# ANALYSIS OF ENERGY AND ENVIRONMENTAL EFFECTS OF THERMAL INSULATION MATERIALS USED FOR EXTERIOR WALLS

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## ABSTRACT

Materials used for thermal insulation of building envelope largely contribute to environmental impacts. The aim of this paper is analysis of thermal insulation materials used for external walls from energy and environmental impacts by method of life cycle assessment. Environmental analysis is focused at the evaluation of embodied energy, emissions of $CO_2$, and $SO_2$ expressed as primary energy intensity (PEI), global warming potential (GWP), and acidification potential (AP), respectively. This study highlights the significant effect of thermal insulation types on environmental impacts. On the other hand a higher specific weight of thermal insulation material improves the heat stability of the building. The obtained results confirm that all thermal insulation on plant base improve the balance of $CO_2$ emissions.

**Keywords**: environmental impact, life cycle assessment, thermal insulation

## 1. Introduction

The construction industry can play a vital role towards sustainable development. Sustainable construction can be achieved with the application of tools that deal with the assessment of the whole life cycle, site planning and organization, material selection, re-use and recycling of materials, waste and energy minimization (Koroneos *et al*. 2007). As we know today′s world is facing major environmental problems i.e. global warming, ozone layer depletion, waste accumulation, etc. (Cabera *et al*, 2014). The construction method of a building offers significant impact on energy use, greenhouse gas (GHG) emissions, and especially global warming potential (GWP) (Wen *et al.* 2015). In general, buildings contribute approximately 30% to total global GHG emissions (Biswas, 2014). The life cycle energy of a residential building consists of the embodied energy involved in the building materials and construction, and the operational energy of the building (Karimpour *et al*. 2014). According to study (Rauf *et al.* 2015) it is therefore of critical importance that energy demand within the built environment is addressed to avoid further degradation of the natural environment. These impacts are not limited to the energy use associated with building operation, but also include energy use associated with all stages of a building's life. The recent studies showed the significance of the energy required for the embodied energy in initial building construction (Rauf *et al*. 2015, Wen *et al*., 2015, Biswas, 2014, Karimpour *et al.* 2014). Life cycle assessment (LCA) as tool to improve sustainability of the construction sector is receiving increasing attention (Buyle *et al*. 2014). The aim of this paper is analysis of thermal insulation materials used for external walls from energy and environmental impacts by method of LCA. Environmental analysis is focused at the evaluation of embodied energy, emissions of $CO_2$, and $SO_2$.

## 2. Methods

Environmental performance of material solutions is calculated by using method of Life cycle assessment (LCA) within boundary "Cradle to Gate". LCA is standardized tool used to assess and report relevant environmental impacts of a product's life cycle. LCA framework is interpreted in international standards of series ISO 14040 - 44 (De Benedetoo *et al*. 2009). The analysis investigates the role of different building material compositions in terms of the embodied energy from non-renewable resources and emissions of $CO_2$ and $SO_2$ in nearly zero energy wooden houses. Embodied energy (EE) is the energy utilized during manufacturing phase of the building materials and represents the energy used to acquire raw materials (excavation), manufacture and transport. Similarly, emissions of $CO_2$ ($ECO_2$, global warming potential GWP) and $SO_2$ ($ESO_2$, acidification potential AP) represent the equivalent emissions within the LCA boundary "Cradle to Gate" and for plant materials take account of absorbing of $CO_2$ during growth stage. The input data of mentioned environmental indicators are extracted from the Austrian LCA database - IBO (Waltjen, 2009). There are proposed 30 material compositions of exterior wall assemblies and designed to meet the value of heat transfer coefficient of U = 0.15 W/m$^2$.K. Material compositions consisting of largely renewable natural resources and designed for nearly zero energy houses in Slovakia are calculated for climatic conditions according to STN EN 730540: 2012: $\theta_e$ - outdoor air temperature (-15°C); $\theta_i$ - indoor air temperature (20°C); $R_{he}$ - relative air humidity in outdoor (84 %); and $R_{hi}$ - relative air humidity in indoor (50 %). Detailed information about evaluated 30 material compositions of exterior wall are listed in Catalog of building structures of wooden houses which was prepared at Faculty of Civil Engineering (Čuláková, 2013). This study is focused on significant effect of thermal insulation types in exterior wall on environmental impacts.

## 3. Results

According to figure (Fig. 1) it can be stated that the thermal insulation, which account for over 40% of the total volume of the materials within the track has the lowest impact on the increase in embodied energy has mainly straw. Effective are also solutions with cork dust, blowing cellulose and sheep wool. If the share of the insulation makes up about 10%, appears to be very advantageous to apply the sheep wool and blown pulp to minimize body of EE.

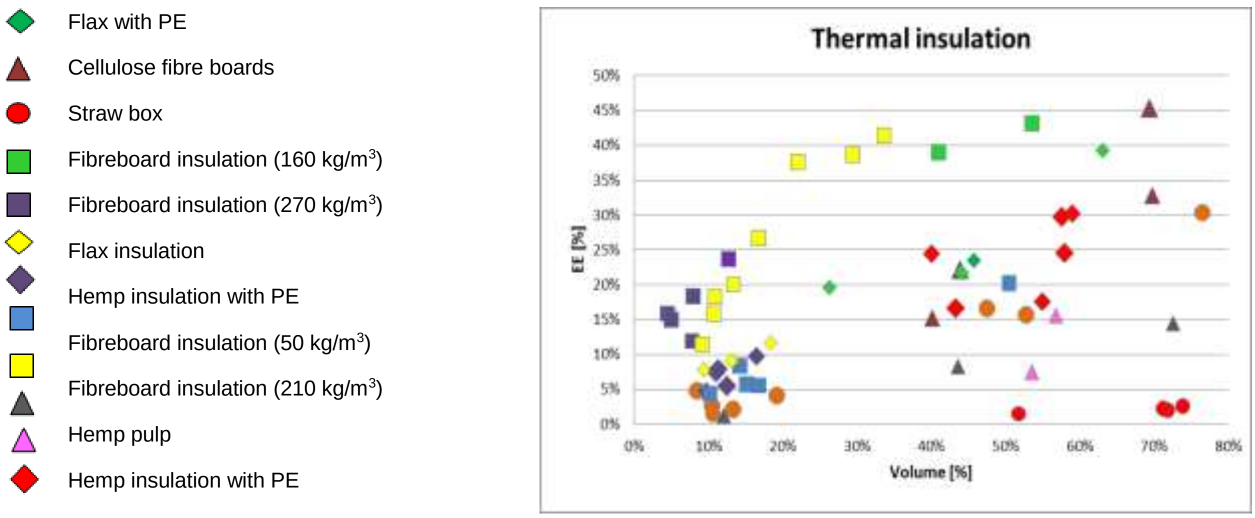


**Figure 1:** The influence of the type of thermal insulation on the percentage of embodied energy, depending on the percentage volume of wall assemblies

High specific volume of thermal insulation material in external wall assemblies has a negative impact on environmental quality; on the other hand a higher specific weight of the material has effect for improving the heat stability of the building. The obtained data confirmed that all thermal insulation plant-based (excluding flax insulation) improve the balance of $CO_{2eq}$ emissions. Flax insulation is subject to more demanding process of preparation in which to produce increased levels of $CO_2$ than a given plant is able to absorb during growth. In cases where flax insulation is more than 40% of the total volume of materials constitutes about 0.69% - 1.67% of the total balance $CO_{2eq}$ emissions investigational assemblies of external walls. Sheep's wool, although it is of animal origin, and therefore does not have negative values of $CO_{2eq}$ emissions, but its processing requires minimal energy input and produces minimal emissions of $CO_2$, which represents 0.19% - 0.73% in the case of compositions of external walls, where it forms more 50% of all the materials. In figure (Fig. 1) is shown percentage of the impact of material groups to the total volume of the application material. In figure (Fig. 3) is shown percentage impact of material groups to the total embodied energy of applied materials.

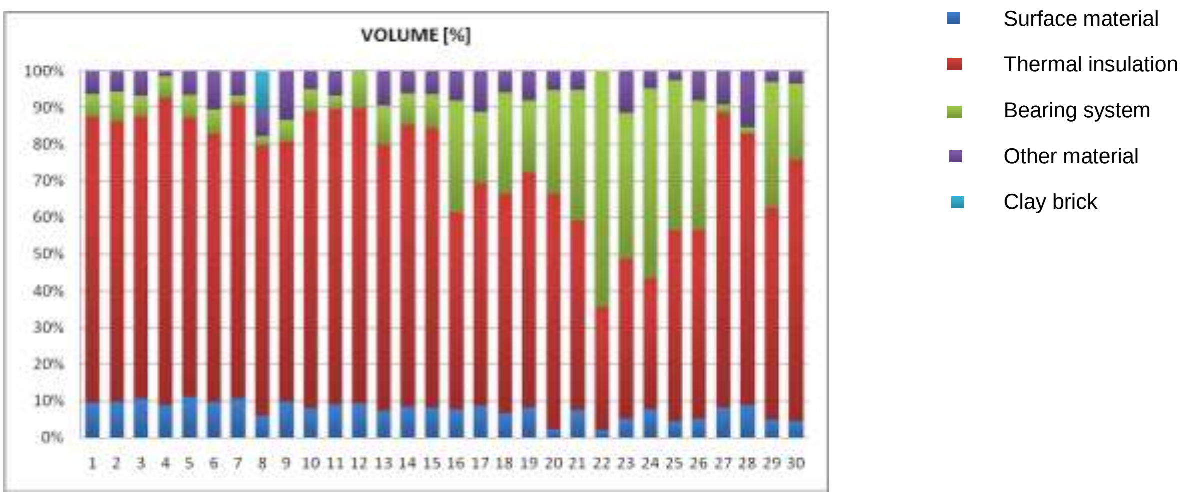


**Figure 2:** Impact of material groups to the total volume of the application material.

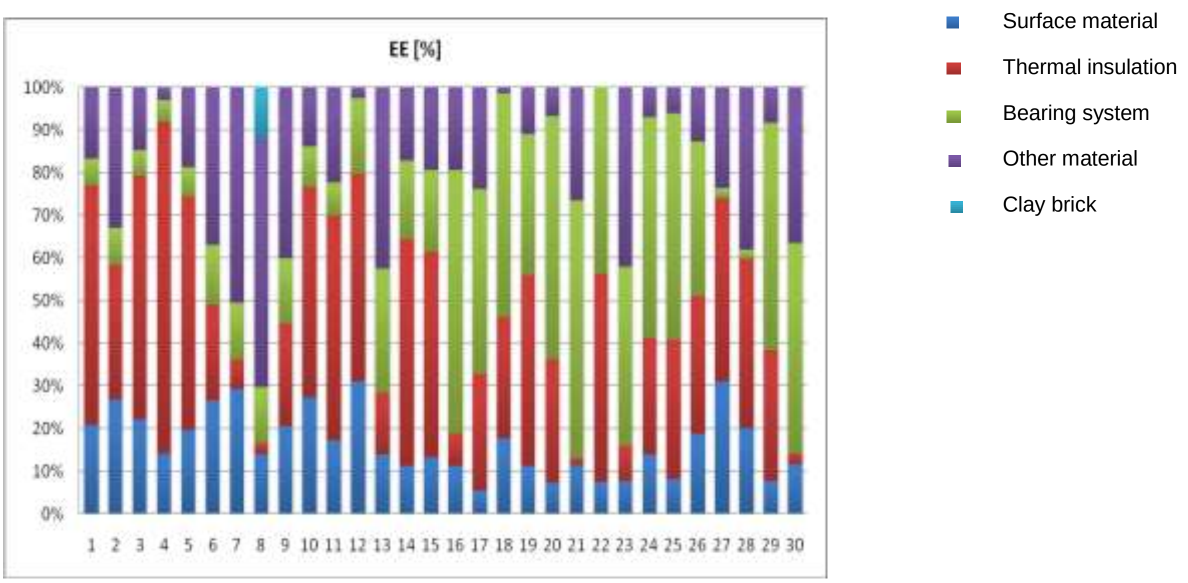


**Figure 3:** Impact of material groups to the total embodied energy of applied materials.

In figure (Fig. 4) is shown percentage impact of material groups for total $CO_2$ emissions of applied materials. In the figure (Fig. 5) is shown percentage impact of material groups for total $SO_2$ emissions of applied materials.

The lowest effect on the preferred environmental indicators has a bearing system of wooden poles (200 x 200 mm, a = 5 m), followed by post system made up of the I-profile fiberboard without isolation. The highest impact related to the large proportion of the total volume of the materials a panel system; the worst of them have environmental quality of CLT panels. To evaluate the characteristics of detail proposed in the Catalogue of external walls was found that all assemblies even taking into account the systematic thermal bridges meet the desired U-value, the minimum value of the inner surface temperature and the linear coefficient of the heat loss. In the context of the value of the linear coefficient of the heat loss is confirmed by the fact that also occurred in the case of appreciation of floor structures that is the best solution if the thermal insulation, interleaving between sections. It has a very positive impact, of course, also cover extra layer of insulation. In terms of impact on the thermal stability of the building it confirmed that the alternatives of external walls with solid timber panels are the best and most effective solution was the wall 8, which consists of clay plaster, clay brick, OSB, flax blocks between I-beams, DHF boards and timber finishes. Significant impact on streamlining the accumulation capacity of the peripheral wall 8 has clay brick.

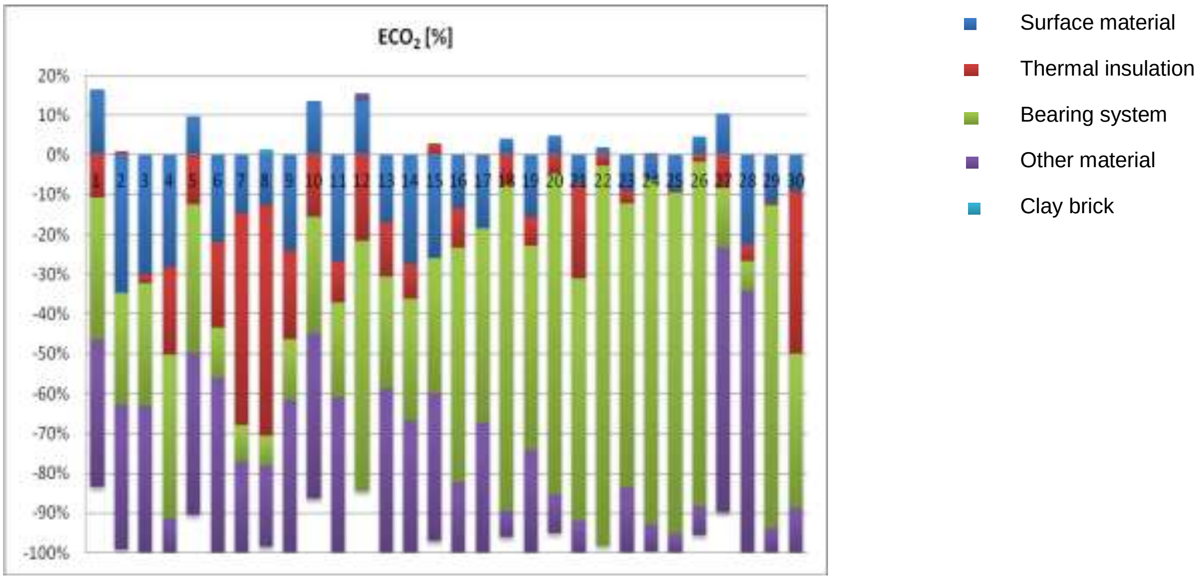


**Figure 4:** Impact of material groups for total $CO_2$ emissions of applied materials

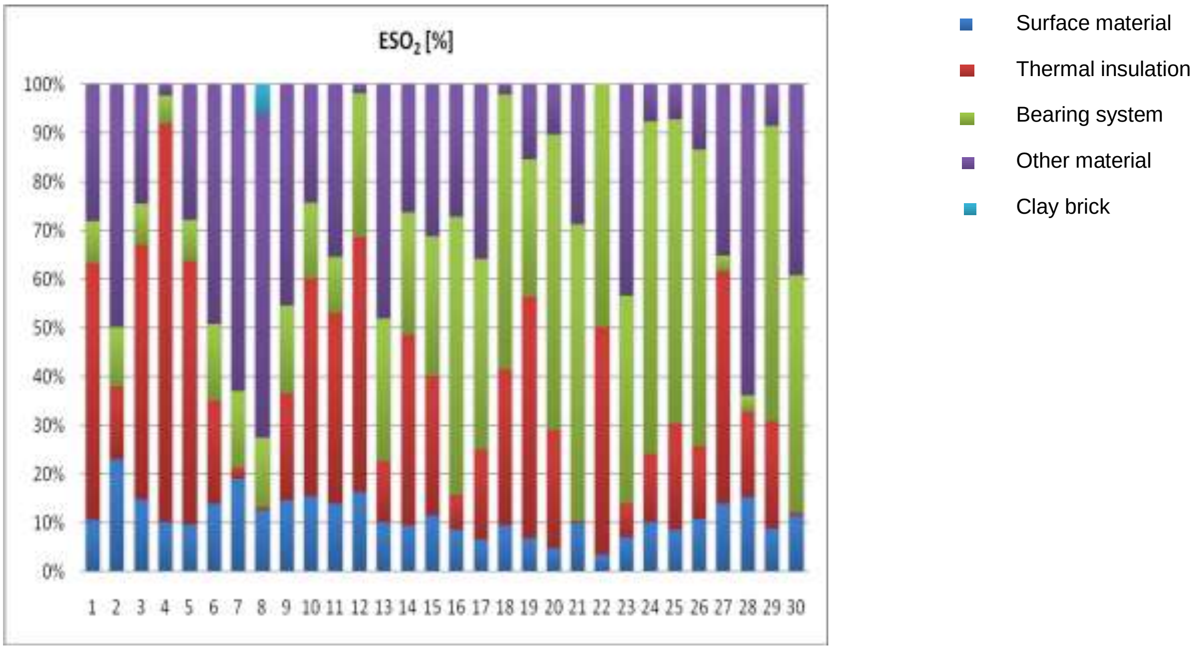


**Figure 5:** Impact of material groups for total $SO_2$ emissions of applied materials.

## 4. Conclusion

This study was focused on highlight the significant effect of thermal insulation types on environmental impacts. On the other hand a higher specific weight of thermal insulation material improves the heat stability of the building. The obtained results confirm that all thermal insulation on plant base improve the balance of $CO_2$ emissions. High specific volume of thermal insulation material in external wall assemblies has a negative impact on environmental quality, on the other hand has a higher specific weight of the material has effect for improving the heat stability of the building. Significant impact on streamlining the accumulation capacity of the peripheral wall 8 has clay brick.


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